March 31, 2007

STATE OF DELAWARE

Delaware Public Service Commission

Electric Service Reliability and Quality Standards

Delmarva Power 2007 Reliability Planning and Studies Report

As stated in the Delaware Public Service Commission (DE-PSC) Regulation Docket No. 50, each electric distribution company (EDC) shall annually submit a reliability planning and studies report to the DE-PSC by March 31. The report requirement is contained in Section 9 of the commission order. This document is presented as Delmarva Power's 2007 Reliability Planning and Studies Report. Section 9 of the commission order is reproduced in the report with Delmarva Power's response inserted after each sub-section.

9.0 Planning and Studies Report

9.1. Prior to March 31 of each year, each EDC shall convene a stakeholder meeting offering opportunity for interested parties to discuss electric service reliability or quality concerns within Delaware. Such meeting shall be limited to discussion of publicly available information and at a minimum be open to generation companies, electric suppliers, municipals or other EDCs, PJM, state agencies and wholesale/retail consumers. Each EDC shall consider the resulting issues and include mitigation efforts in annual plans as appropriate.

Response 9.1: Stakeholders meeting completed as follows:

Day – Date - Time	Location	Discussion Topics
Monday, February 26, 2007, 1:00 PM	Delaware PSC Hearing Room 861 Silver Lake Blvd. Cannon Bldg. Suite 100 Dover, DE 19904	Electric Service Reliability or Quality Concerns within Delmarva Power's Service Territory

The stakeholder meeting convened at approximately 1:15 PM with no individuals from generation companies, electric suppliers, municipals or other EDCs, PJM or wholesale / retail customers attending. The meeting was publicized in the News Journal and the Delaware State News. See Attachment 1, Public Notice of Stakeholder Meeting and Affidavits of Publication.

9.2. By March 31 of each year, each EDC shall submit a reliability planning and studies report to the Commission for review. The report will identify current reliability objectives, load study results and planned actions, projects or programs designed to maintain the electric service reliability and quality of the delivery facilities.

Response 9.2:

This document is presented as Delmarva Power's 2007 Reliability Planning and Studies Report.

9.3. The report shall include the following information:

9.3.1. Objective targets or goals in support of reliable electric service and descriptions of planned actions to achieve the objectives;

Response 9.3.1:

Delmarva Power has no specific objective targets or goals in support of reliable electric service in the State of Delaware. Rather, programs are designed to maintain a minimum (and improve upon wherever possible) performance level of 295 minutes as measured by the System Average Interruption Duration Index (SAIDI) in accordance with paragraph 4.3 of the Electric Service Reliability and Quality Standards set forth in Regulation Docket No. 50. Planning studies are conducted to determine where new equipment should be installed to improve service.

In addition to the identified capital improvements listed in Section 9.3.3, the following priority feeder program is in place to support improvement in reliable electric service:

All Delmarva Power distribution feeders were ranked by relative performance using a composite performance indexing method that considers both outage frequency and duration in the ranking calculation. For the 2007 program, feeders were ranked using performance values for the period October 1, 2005 to September 30, 2006. Ten of the least reliable feeders in Delaware were selected to receive a technical evaluation (consisting of a historical outage review, design review, and field observations), and modifications (in most cases) based on the evaluation. Feeder modifications are now being designed and are planned to be performed by December 31, 2007. The Performance Report to be issued by April 30, 2007, will provide more detail on the composite performance ranking method used in the priority feeder program.

Delmarva Power has other programs in place to support reliability as noted in this document. In Section 9.3.4 contains the power quality program guideline. The maintenance program is presented in Section 9.3.5 and Section 9.3.7 includes information on the company's participation in organizations that establish reliability standards. All customer reliability inquires are investigated and resolved.

9.3.2. Delivery load study results as described in Section 8, to include at a minimum the information for both year b and year c as specified in Section 8, Paragraph 3;

Section 8 is reproduced here for reference:

8.0 Delivery Facility Studies

8.1. Each EDC shall perform system load studies to identify and examine potential distribution circuit overloads, distribution substation and distribution substation supply circuit single contingencies and all transmission system single and double contingencies as specified by NERC, MAAC, Reliability First Corp. and PJM or successor requirements. Double contingency analysis should include supply service contingencies that may cause overloads or outages on the EDC's system. Where NERC, MAAC, Reliability First Corp or PJM requirements are not applicable, the EDC shall at a minimum examine circuit and equipment overloads under normal and single contingency conditions at peak load, with and without ALM or other demand response mechanisms. The EDC shall identify all projects and/or corrective actions that are planned to mitigate reliability loading issues identified in the study.

8.2. Delivery facility planning studies will be performed annually under conditions specified by NERC, MAAC, Reliability First Corp. and PJM or their successor organization's planning requirements, or as specified in 8.1. Studies shall identify required projects and/or planned corrective actions. For any study resulting in a thermal overload or an out-of-range voltage level, the study shall be performed again after the implementation of Active Load Management (ALM), system switching or reconfiguration.

8.3. Each EDC shall perform the electric delivery facility system planning studies as described herein in the fall of each year (year a) for the upcoming summer period (year b) and for the summer period two years later (year c). The planning studies will include all delivery facility enhancements planned to be in-service during the applicable summer peak and shall identify those delivery facilities that are anticipated to be overloaded during the peak demand period.

Response 9.3.2:

The results of the system planning studies are included in the project list in Section 9.3.3.

The PJM RTEP Report dated February 27, 2007 satisfies this requirement. This report includes all planning studies through a 5 year period with identified system reinforcements. Reference Response to Section 9.3.6.

9.3.3. Description and estimated cost of capital projects planned to mitigate loading or contingent conditions identified in load studies or required to manage hours of congestion;

Response 9.3.2 and 9.3.3:

Description	Scheduled ISD	Estimated Total Cost (thousands)	Driver
Southern New Castle County 69kV to 138kV Conversion	5/31/2007	$18,264	Load
Rebuild Cheswold to Kent 69kV	5/31/2007	$2,279	Load
Town of Lewes – Switch Replacements on 6751	5/31/2007	$339	Reliability
New Castle Sub Feeders 167 & 169. Transfers and Upgrades	6/15/2007	$368	Load
Five Points/Midway/Rehoboth Substations Reconductor Feeder Sections	6/30/2007	$326	Load
Five Points Substation Feeder 528 Reconductor	6/30/2007	$185	Load
Kent Substation Feeder 2233. Install Recloser and Regulator	6/30/2007	$149	Load
Keeney Substation – 500kV Breaker Replacement	10/31/2007	$3,164	Reliability
Planned Distribution Cable Replacement	12/31/2007	$374	Reliability
Priority Feeder Improvements (Includes all of Delmarva Power)	12/31/2007	$1,475	Reliability
Upgrade Rehoboth to Cedar Neck Tap (6733-2) 69kV	5/31/2008	$1,797	Load
Cedar Neck Substation Feeder 531 Reconductor	5/31/2008	$615	Load
North Seaford – Add 2nd 138/69kV Transformer	5/30/2008	$3,852	Load
Mt. Pleasant Substation. Add 2nd 138/25kV Transformer	5/31/2009	$2,080	Load
Red Lion Substation – 500/230kV Work	5/31/2009	$15,758	Load
Indian River 138/69kV Transformer Replacement	5/31/2009	$6,617	Load

9.3.4. The EDC's power quality program and any amendments as required in Section 6;

Section 6 is reproduced here for reference:

6.0 Power Quality Program

6.1. Each EDC shall maintain a power quality program with clearly stated objectives and procedures designed to respond promptly to customer reports of power quality concerns.

6.2. Each EDC shall consider power quality concerns in the design, construction and maintenance of its transmission and distribution power delivery system components to mitigate, using reasonable measures, power quality disturbances that adversely affect customers' equipment.

6.3. Each EDC shall maintain records of customer power quality concerns and EDC response. These records shall be made available to the Commission Staff upon request with 30 days notice.

Response 9.3.4: The power quality program policy guideline is included with this document as Attachment #2 and remains unchanged from the 2006 Reliability Planning & Studies Report.

9.3.5. The EDC's inspection and maintenance program, any amendments as required in Section 7, and any specific actions aimed at reducing outage causes;

Section 7 is reproduced here for reference:

7.0 Inspection and Maintenance Program

7.1. Each EDC shall have an inspection and maintenance program designed to maintain delivery facilities performance at an acceptable reliability level. The program shall be based on industry codes, national electric industry practices, manufacturer's recommendations, sound engineering judgment and past experience.

7.2. As a maintenance minimum, each EDC shall inspect and maintain as necessary its power transformers, circuit breakers, substation capacitor banks, automatic 3-phase circuit switches and all 600 amp or larger manually operated, gang transmission circuit tie switches at least once every two (2) years.

7.3. As a maintenance minimum, each EDC shall inspect all right-of-way vegetation at least once every four (4) years and trim or maintain as necessary, according priorities to circuits that have had significant numbers of vegetation-related outages, while not unduly delaying the trimming of other circuits that inspections indicate currently need trimming. Vegetation management practices should be applied at least once every four (4) years except where growth or other assessments deem it unnecessary.

7.4. Each EDC shall maintain records of inspection and maintenance activities. Compliance with this requirement may be established by a showing of substantial compliance without regard for a single particular facility maintenance record. These records shall be made available to Commission Staff upon request with 30 days notice.

Response 9.3.5:

Substation

Circuit Breakers

	Vacuum Circuit Breakers	Air Circuit Breakers	SF-6 Breakers	Oil Circuit Breakers	Oil Circuit Breakers	SF-6 Breakers
	4, 12, 25, & 34KV	**4, 12, 25, & 34KV**	**12, 25, & 34KV**	**4, & 12, 25 & 35KV**	**69, 138, & 230KV**	**69, 138, 230 & 500KV**
External Testing/Maint. Cycle	6 - 10 yrs.	8 - 10 yrs.	8 yrs.	6 -10 yrs.	6 - 10 yrs.	8 yrs.
Infrared Inspection	Annually	Annually	Annually	Annually	Annually	Annually
Internal Inspection	Based on test results	Based on test results	Based on test results	8 yrs. / Based on test results	12 yrs. / Based on test results	Based on test results
Test Requirements						
Gas Analysis Test	No	No	No	No	No	Yes
Doble Pf. Test	No	12, 23, & 34kv only	Yes	Yes	Yes	Yes
Ductor	Yes	Yes	Yes	Yes	Yes	Yes
Hi-Pot Vacuum Bottles	Yes	N/A	N/A	N/A	N/A	N/A
Analyze/Timing Test	Stand alone breakers only	N/A	Yes	Yes	Yes	Yes
Oil Power Factor (ASTM D924)	N/A	N/A	N/A	Yes	Yes	N/A
Dielectric Breakdown (ASTM D-877)	N/A	N/A	N/A	Yes	Yes	N/A

Substations

Power Transformers

	POWER TRANSF.	MOBILE UNIT TRANSFORMERS	LTC's
Testing/Maintenance Cycle	6 - 10 Yrs.	Annual External Inspection	6 – 10 yrs. Or Condition based
Infrared Inspection	Annually		Annually
Doble Power Factor Testing			N/A
Overall Insulation Test	Yes	Yes	"
Bushing Tests; C1 & C2	Yes	Yes	"
Hot Collar Test -W/O Pf Tap	Yes	Yes	"
Excitation Test	@ existing tap setting	@ existing tap setting	N/A
LTC Position (16L,16R)	Yes	Yes	
Limited TTR	@ existing tap setting	@ existing tap setting	N/A
LTC Tap Position (16L,1L,N,16R)	if applicable	N/A	
Dissolved Gas in Oil/Oil Quality Checks			
Dissolved Gas Analysis	Annually	Annually	Annually
Dielectric Breakdown	Annually	Annually	Annually
Acid Number (ASTM D-1534)	Annually	Annually	Annually
Color (ASTM D-1524)	Annually	Annually	Annually
Moisture	Annually		
Oil Power Factor Test	Yes	Yes	Yes
Supplemental Tests			
Ductor (Resistance Test)	W/Doble Pf Test	W/Doble Pf Test	N/A
Meggar Test	W/Doble Pf Test	W/Doble Pf Test	N/A
Doble Hot Collar-Bushing with Pf. Tap	W/Doble Pf Test	W/Doble Pf Test	N/A

Substations

Switches

	Motor Operated Disconnect Switches w/Relay Scheme	Circuit Switchers
Maintenance	N/A	Operate with other equipment maintenance outages
Cycle		Annual External Inspection
Infrared Inspection	Annually	Annually
Maintenance performed in conjunction with other equipment	Yes	Yes
Test Requirements	Per Manufacturer Recommendations	Per Manufacturer Recommendations

Miscellaneous Equipment

	Lightning Arresters	Potential/ Current Transf.	Potential/ Current Transf.	Relay / Communication Transmission	Relay / Communication Distribution
		<=34.5Kv	**>=69Kv**		
Maintenance Cycle	N/A	N/A	N/A	4 yrs.	8 yrs. (4 yrs UV & UF)
Battery System	N/A	N/A	N/A	Annually	Annually
Maintenance performed in conjunction with other equipment	Yes	Yes	Yes	Yes	Yes
Infrared Inspection	Yes	Yes	Yes	N/A	N/A
Visual Inspection	Yes	Yes	Yes	N/A	N/A
Doble Power Factor Test	Condition based	Condition based	Condition based		

Transmission Maintenance Plan Summary

- Transmission wood pole inspection	12 to 15 year cycle
- Transmission infrared inspection	Annually
- Transmission vegetation management Aerial inspection semi-annually	Reliability based program
- High Pressure Oil or Gas Filled Cable Systems	Annually
- Communication / Tower Aviation Warning Lights	Annually
- Visual check of navigable water crossings	5 year cycle
- Transmission aerial inspection, "fly by"	3 year cycle
- Transmission aerial inspection, comprehensive	Bulk supply lines – 5 year cycle

Distribution Maintenance Plan Summary

- Street Light Group Replacement	6 year cycle
- Inspection of Switch Capacitor Banks	Annually
- Inspection of Fixed Capacitor Banks	Annual visual inspection
- Full operational check of Reclosers and Sectionalizers	Electronic Controls tested every 3 – 6 years
- Visual inspection electronically controlled reclosers	Annually
- Distribution wood pole inspections	12 to 15 year cycle
- Inspection of Pad Mounted Distribution Facilities	15 to 30 Year cycle
- Distribution Vegetation Management	Reliability based program
- Distribution infrared inspection	5 year cycle
- Visual check of navigable water crossings	5 year cycle (Infrared Inspection)

9.3.6. Copies of all recent delivery facility planning studies and network capability studies (including CETO and CETL results) performed for any delivery facilities owned by the utility; and

Response 9.3.6:

The information is available at the PJM Web Site. The web site address is:

Regional Transmission Expansion Plan issued 02/27/2007

The documents are also included on the enclosed CD – ROM.

9.3.7. Summaries of any changes to reliability related requirements, standards and procedures at PJM, MAAC, First Reliability Corporation, NERC or the EDC.

Response 9.3.7:

"Control-Click" on any web page link to access that document or web page.

PJM Reliability Standards:

Reference the PJM Manual 14B: Generation and Transmission Interconnection Planning Revision 10 dated March 1, 2007 at the PJM Web Site.

Additional information on planning parameters may be reviewed at

PJM Planning Parameters

The documents at this address include:

Document	Posting Date
Planning Period Parameters	03/02/2007
Key Expected Transmission Upgrades	02/15/2007
Summer Coincident Peak Load for 2007 - 2010	01/08/2007
FRR Resources 2007-2008	03/07/2007
RPM Resource Model	01/26/2007

MAAC Reliability Standards:

The following web site lists the MAAC Reliability Standards.

MAAC Reliability Standards and Documents

No changes occurred in 2006. There have been no updates since 2005.

Reliability First Reliability Standards:

The following web site lists the approved Reliability First Reliability Standards.

Reliability First Standards

Those standards having a 2006 effective date were added or revised from the previous version in 2006.

NERC Reliability Standards:

The following web site lists the approved NERC Reliability Standards.

NERC Reliability Standards – BOT Approved

Those standards having a 2006 effective date were added or revised from the previous version in 2006.

The following web site includes a list of NERC Reliability Standards that were retired.

NERC Reliability Standards – Retired / Withdrawn

Those standards having a 2006 end date were retired in 2006. In most if not all cases, the retired standards were replaced by a newer version.

NERC has a three year plan to review and revise the reliability standards accessible with the link below:

Reliability Standards Development Plan Volume I, II, III 11/30/2006

Those NERC and Reliability First Reliability Standards or Requirements that list Transmission Owner, Distribution Provider, Load Serving Entity, or Purchasing-Selling Entity as the applicable entity apply to Delmarva Power.

The NERC Reliability Standard numbering convention has three parts:

1. A three-letter acronym denoting the general topical area of the standard.
2. The standard number within that topical area, beginning with 1 and increasing sequentially.
3. The version of that standard.

Example: BAL-001-1 (Balancing – Standard 001 – Version 1)

The Reliability First Standard numbering convention has the same three parts but is preceded by RFC for Reliability First Corporation.

Example: RFC-EOP-001-0 (Emergency Preparedness – Standard 001 – Version 0)

The version number is changed when changes are made to the standard through the standards development procedure.

The web page links are provided here:

NERC Reliability Standards Development Procedure Version 6.0 11/01/2006

Reliability Standards Developmental Procedure 020807

9.3.8. Summary of any issues that resulted from the EDC stakeholder meeting and any projects or planning changes that may have been incorporated as a result of such meeting.

Response 9.3.8:

As stated in the response to item 9.1, the stakeholder meeting convened, as scheduled, at approximately 1:15 PM on February 26th, 2007 with no individuals from generation companies, electric suppliers, municipals or other EDCs, PJM or wholesale / retail customers attending. Accordingly, no issues were identified at that time. Old Dominion Electric Cooperative (ODEC) submitted written concerns on January 16, 2007 regarding delivery point outages on behalf of Delaware Electric Cooperative (DEC). While no specific projects or planning changes have been incorporated in this report as a result of the ODEC inquiry, corrective actions taken to address the ODEC issues were discussed by Delmarva Power at a meeting on March 8, 2007 attended by ODEC and DEC representatives.

CD ROM Document Index

RTEP Report Section	File Name
Table of Contents and Preface	20070301-contents-and-preface.pdf
Section 1 – Executive Summary	20070301-section-01.pdf
Section 2 – Developing an Expansion Plan	20070301-section-02.pdf
Section 3 – PJM Board Approved 15 Year Expansion Plans: 2006-2021: File 1	20070301-section-03a.pdf
Section 3 – PJM Board Approved 15 Year Expansion Plans: 2006-2021: File 2	20070301-section-03b.pdf
Section 3 – PJM Board Approved 15 Year Expansion Plans: 2006-2021: File 3	20070301-section-03c.pdf
Section 4 – Development of New Solutions 2006-2021: File 1	20070301-section-04a.pdf
Section 4 – Development of New Solutions 2006-2021: File 2	20070301-section-04b.pdf
Section 5: State RTEP Overviews: File 1 – State RTEP Overviews	20070301-section-05-state-overviews.pdf
Section 5: State RTEP Overviews: File 2 – Delmarva Peninsula	20070301-section-05-delmarva.pdf
Section 5: State RTEP Overviews: File 6 – Maryland and District of Columbia	20070301-section-05-maryland-and-dc.pdf
Section 5: State RTEP Overviews: File 8 – New Jersey	20070301-section-05-new-jersey.pdf
Section 6: Glossary	20070301-section-06-glossary.pdf
RTEP System Reinforcements as of 03.01.2007	20070301-rtep-reinforcements.pdf
PJM Manual 14B: Generation and Transmission Interconnection Planning Revision 10 dated March 1, 2007	PJM Manual 14B R10.pdf
PJM Planning Parameters	
Planning Period Parameters	planning-period-parameters.xls
Key Expected Transmission Upgrades	transmission-upgrades.xls
Summer Coincident Peak Load for 2007-2010	2007-cp-forecast.pdf
FRR Resources 2007-2008	frr-resources-2007-2008.xls
RPM Resource Model	Rpm-resource-Ida-2007-2008.xls

CD ROM Document Index

Standards	File Name
MAAC Reliability Standards	Reliability Principles & Standards.pdf
Reliability First Reliability Standards	Automatic Reserve Sharing RFC-ARS-001-0_Approved_12-12-05.pdf
	Emergency Operations Plans RFC-EOP-001-0_Approved_12-12-05.pdf
	Operating Reserves RFC-OPR-001-0_Approved_12-12-05.pdf
	Reliability Standards Development Procedure 20020807.pdf
	Resource Planning Reserve Requirements RFC-RES-001-1_032406.pdf
	System Restoration Plans RFC-EOP-004-0_Approved_12-12-05.pdf
	Trans Emergency Action Plan RFC-EOP-003-0_Approved_12-12-05.pdf
NERC Reliability Standards	FERC_Filing_Volumes_I-II-III_Reliability_Standards_Development_Plan_30Nov06.pdf
	RSDP_V6_01Nov06.pdf

Attachment 1: Public Notice of Stakeholder Meeting

P U B L I C   N O T I C E

ELECTRIC SERVICE RELIABILITY

TO: **GENERATION COMPANIES, ELECTRIC SUPPLIERS, MUNICIPALS OR OTHER EDC'S, PJM , STATE AGENCIES AND WHOLESALE/RETAIL CONSUMERS OF DELMARVA POWER & LIGHT COMPANY, WITHIN THE STATE OF DELAWARE,**

In accordance with PSC Order No. 6925, Delmarva Power shall convene a stakeholder meeting offering opportunity for interested parties to discuss electric service reliability or quality concerns within Delmarva Power's service territory. The meeting shall be limited to discussion of publicly available information. The Company shall consider the resulting issues and include mitigation efforts in annual plans as appropriate.

Meeting Information

Day – Date - Time	Location	Discussion Topic
Monday, February 26, 2007, 1:00 PM	Delaware PSC Hearing Room 861 Silver Lake Blvd. Cannon Bldg. Suite 100 Dover, DE 19904	Electric Service Reliability or Quality Concerns within Delmarva Power's Service Territory

Parties with electric reliability or quality concerns, and unable to attend the meeting, may offer written comment by mail or e-mail to Delmarva Power and the Public Service Commission at the following addresses:

Public Service Commission
861 Silver Lake Blvd.
Cannon Bldg., Suite 100
Dover, DE 19904
Robert.Howatt@state.de.us

Delmarva Power
401 Eagle Run Road
P.O. Box 9239
Newark, DE 19714-9239
Gary.Cohen@PepcoHoldings.com

All written comment received will become a matter of public record and available to all parties.

Individuals with disabilities who wish to participate in these proceedings or to review the filings may contact the Commission to discuss any auxiliary aids or services needed to facilitate such review or participation. Such contact may be in person, by writing, by use of voice, text, or relay telephone, or otherwise. The Commission's toll-free telephone number within Delaware is 1-800-282-8574. The Commission can also be reached at (302) 739-4247 and that number should also be used for Text Telephone ("TT") calls.

Attachment #1

Mailing:
The News Journal
PO Box 15505
Wilmington, DE 19850

Street
The News Journal
950 W. Basin Road
New Castle, DE 19720
(302) 324-2500

Sunday News Journal
The News Journal

The News Journal

AFFIDAVIT OF PUBLICATION

STATE OF DELAWARE COUNTY OF NEW CASTLE

Personally appeared before me this 23rd day of January, 2007:

I, Melissa Michelson, of the NEWS JOURNAL COMPANY, a daily newspaper printed and published in the County of New Castle County, State of Delaware, who, being duly sworn states that the advertisement of Delmarva Power-Public Notice-Electric Service Reliability was published in THE NEWS JOURNAL on January 23, 2007 and/or THE SUNDAY NEWS JOURNAL on n/a

Melissa Michelson
Name

Legal Coordinator
Title

Sworn to before me this 23rd day of January, 2007

Elizabeth A. Kobek
Notary Public

Attachment #1

PUBLIC NOTICE

ELECTRIC SERVICE RELIABILITY

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1|23-NJ OI0110377588

Attachment #1

Independent Newspapers, Inc.

P.O. Box 7001 • Dover, Delaware • 19903 • 1-800-282-8586

State of Delaware:
:ss.
Counties of Kent:

Before me, a Notary Public, for the County and State aforesaid, Wanda Ford-Waring, known to me to be such, who being sworn according to law deposes and says that she is an officer of Independent Newspaper Inc, the Publisher of the The Delaware State News, a daily newspaper published at Dover, County of Kent, and State of Delaware, and that the notice, a copy of which is hereto attached, as published in the The Delaware State News in its issue of January 20, 2007.

Vice President, Corporate Services
Independent Newspapers, Inc.

Sworn to and subscribed before me this 26th
Day of February A.D. 2007

Janet Kelly
Notary Public

Attachment #1

Public Notice 5005 | Public Notice 5005

PUBLIC NOTICE

ELECTRIC SERVICE RELIABILITY

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QUALITY OF DELIVERY VOLTAGE GUIDELINES

Purpose

The purpose of this section is to provide technical information and a process for the resolution of customer power quality complaints. Power quality (PQ) has become a concern for many of our customers and for Atlantic City Electric & Delmarva Power. Voltage variations that once were considered normal can cause today's electronic equipment to trip off line or even fail.

Requirements

Although the state rules vary, overall the standards are loosely defined. Atlantic City Electric & Delmarva Power's internal design philosophy exceeds all state requirements throughout the service territory.

The information in this section was condensed from the Quality of Delivery Voltage Guidelines (full report), Power Quality Guidelines, and the following documents in four states:

Delaware: from "Regulations Governing Service Supplied by Electric Utilities," Rule 16 Voltage (Sections A2, A3, B and F). This document was written in 1952 and has not changed since then.

Maryland: from "Code of Maryland Regulations", Title 20, Subtitle 50, Chapter 07. This chapter was written in 1942 with the last update made in 1965. The commission staff in 1997 did not anticipate any modifications to this chapter.

New Jersey: from "New Jersey Administrative Code" (NJAC), 1980, Sections 14:5 – 2.3 Adequacy of Services and 14:5 – 7.5 Power Quality.

Virginia: from "Virginia Rules and Regulations" in Atlantic City Electric & Delmarva Power's Tariff Section XI - Customer Use of Service. These rules and regulations for the Virginia service territory meet the requirements of the state. Virginia staff members reported in 1997 that these rules have been on the books for decades and there are no plans to change this section.

Information Resource

For additional assistance, questions, or customer consultations, contact a Power Quality Contractor.

Table I Voltage Limitations Defined by State

State	Steady State Criteria	Transient Voltage Fluctuations	Flicker Limitations	Maximum Harmonic Distortion	Maximum Voltage Unbalance
Delaware	±5%	Undefined	Continuous fluctuations not to exceed ±3% change in one second or less	Undefined	Undefined
Maryland	+5%, -10% for secondary service	Undefined	Undefined	Undefined	Undefined
	±7.5% for primary service	Undefined	Undefined	Undefined	Undefined
New Jersey	±4%	Undefined	Undefined	Undefined	Undefined
Virginia	±5% for urban residential areas	Undefined	Undefined	Undefined	Undefined
	±7.5% for non-urban and all others	Undefined	Undefined	Undefined	Undefined

[1]It should be noted that there will be exceptions to the voltage requirements. A typical definition of these exceptions is defined in the Maryland Regulations under Title 20.50.07.02 Voltage Limits... "It will **not** be considered a violation when voltages outside of the prescribed limits are caused by any of the following:

1. Action of the elements
2. Service interruptions
3. Temporary separation of parts of the system from the main system
4. Infrequent fluctuations not exceeding 5 minutes duration
5. Other causes beyond the control of the utility

NORMAL, STEADY STATE VOLTAGE

Definition of Normal Voltage Ranges

All four state jurisdictions define acceptable variations in steady state voltage. Only the State of Maryland Regulations, among the states served by Atlantic City Electric & Delmarva Power, define nominal acceptable secondary voltages.

The following paragraphs and Table II are adopted from ANSI-C84.1-1989 which defines nominal system voltages and voltage ranges. It is worth noting that on Table II the limits of Range A and Range B apply to steady state voltage levels and not to momentary voltage excursions that may result from such causes as switching operations, motor starting currents, etc.

RANGE A - SERVICE VOLTAGE... Electric supply systems shall be so designed and operated that most service voltages will be within the limits specified for Range A. The occurrence of voltages outside of these limits should be infrequent. Service voltage is defined as the voltage at the point where the electrical system of the supplier and the electrical system of the user are connected.

RANGE A - UTILIZATION VOLTAGE... User systems shall be so designed and operated that, with service voltages within Range A limits, most utilization voltages will be within the limits specified for this range. Utilization equipment shall be designed and rated to give fully satisfactory performance throughout this range.

RANGE B - SERVICE AND UTILIZATION VOLTAGES... Range B includes voltages above and below Range A limits that necessarily result from practical design and operating conditions on supply or user systems, or both. When they occur, corrective measures shall be undertaken within a reasonable time to improve voltages to meet Range A requirements. Equipment shall be designed to give acceptable performance in the extremes of the range of utilization voltages, although not necessarily as good performance as Range A. When voltages occur outside the limits of Range B, prompt corrective action shall be taken.

If information is needed for nominal voltages and acceptable operating ranges for systems above 230 kV refer to ANSI-C92.2-1987.

Table I— Standard Nominal System Voltages and Voltage Ranges

(Preferred system voltages in bold-face type)

VOLTAGE CLASS	NOMINAL SYSTEM VOLTAGE (Note a) Two-wire	Three-wire	Four-wire	Nominal Utilization Voltage (Note i) Two-wire Three-wire Four-wire	VOLTAGE RANGE A (Note b) Maximum: Utilization and Service Voltage (Note c)	Minimum: Service Voltage	Minimum: Utilization Voltage	VOLTAGE RANGE B (Note b) Maximum: Utilization and Service Voltage	Minimum: Service Voltage	Minimum: Utilization Voltage
					Single-Phase Systems					
Low Voltage (Note 1)	120			115	126	114	110	127	110	106
		120/240		115/230	126/252	114/228	110/220	127/254	110/220	106/212
					Three-Phase Systems					
			208Y/120 (Note d)	200	218Y/126	197Y/114	191Y/110	220Y/127	191Y/110 (Note 2)	184Y/106 (Note 2)
			240/120	230/115	252/126	228/114	220/110	254/127	220/110	212/106
		240		230	252	228	220	254	220	212
			480Y/277	460	504Y/291	456Y/263	440Y/254	508Y/293	440Y/254	424Y/245
		480		460	504	456	440	508	440	424
		600 (Note e)		575	630 (Note e)	570	550	635 (Note e)	550	530
Medium Voltage		2 400			2 520	2 340	2 160	2 540	2 280	2 080
			4 160Y/2 400		4 370/2 520	4 050Y/2 340	3 740Y/2 160	4 400Y/2 540	3 950Y/2 280	3 600/2 080
		4 160			4 370	4 050	3 740	4 400	3 950	3 600
		4 800			5 040	4 680	4 320	5 080	4 560	4 160
		6 900			7 240	6 730	6 210	7 260	6 560	5 940
			8 320Y/4 800		8 730Y/5 040	8 110Y/4 680	(Note f)	8 800Y/5 080	7 900Y/4 560	(Note f)
			12 000Y/6 930		12 600Y/7 270	11 700Y/6 760		12 700Y/7 330	11 400Y/6 580	
			12 470Y/7 200		13 090Y/7 560	12 160Y/7 020		13 200Y/7 620	11 850Y/6 840	
			13 200Y/7 620		13 860Y/8 000	12 870Y/7 430		13 970Y/8 070	12 504Y/7 240	
			13 800Y/7 970		14 490Y/8 370	13 460Y/7 770		14 520Y/8 380	13 110Y/7 570	
		13 800			14 490	13 460	12 420	14 520	13 110	11 880
			20 780Y/12 000		21 820Y/12 600	20 260Y/11 700	(Note f)	22 000Y/12 700	19 740Y/11 400	(Note f)
			22 860Y/13 200		24 000Y/13 860	22 290Y/12 870		24 200Y/13 970	21 720Y/12 540	
		23 000			24 150	22 430		24 340	21 850	
			24 940Y/14 400		26 190Y/15 120	24 320Y/14 040		26 400Y/15 240	23 690Y/13 680	
			34 500Y/19 920		36 230Y/20 920	33 640Y/19 420		36 510Y/21 080	32 780Y/18 930	
		34 500			36 230	33 640		36 510	32 780	
					Maximum Voltage (Note g)					
		46 000			48 300					
		69 000			72 500					
High Voltage		115 000			121 000					
		138 000			145 000					
		161 000			169 000					
		230 000			242 000					
		(Note h)								
Extra-High Voltage		345 000			362 000					
		500 000			550 000					
		765 000			800 000					
Ultra-High Voltage		1 100 000			1 200 000					

NOTES: (1) Minimum utilization voltages for 120-600 volt circuits not supplying lighting loads are as follows:

	Nominal System Voltage	Range A	Range B
	120	108	104
	120/240	108/216	104/208
(Note 2)	208Y/120	187Y/108	180Y/104
	240/120	216/108	208/104
	240	216	208
	480Y/277	432Y/249	416Y/240
	480	432	416
	600	540	520

(2) Many 220 volt motors were applied on existing 208 volt systems on the assumption that the utilization voltage would not be less than 187 volts. Caution should be exercised in applying the Range B minimum voltages of Table 1 and Note (1) to existing 208 volt systems supplying such motors.

Notes:

a) Three-phase three-wire systems are systems in which only the three-phase conductors are carried out from the source for connection of loads. The source may be derived from any type of three-phase transformer connection, grounded or ungrounded. Three-phase four-wire systems are systems in which a grounded neutral conductor is also carried out from the source for connection of loads. Four wire systems in Table II are designated by the phase-to-phase voltage, followed by the letter Y (except for 240/120 volt delta system), a slant line, and the phase-to-neutral voltage. Single-phase services and loads may be supplied from either single-phase or three-phase systems.

b) The voltage ranges in this table are illustrated in the full ANSI Standard, Appendix B.

c) For 120-600 volt nominal systems, voltages in this column are maximum service voltages. Maximum utilization voltages would not be expected to exceed 126 volts for the nominal system voltage of 120, nor appropriate multiples thereof for other nominal voltages through 600 volts.

d) A modification of this three-phase, four-wire system is available as a 120/208 Y volt service for single-phase, three-wire, open-wye applications.

e) Certain kinds of control and protective equipment presently available have a maximum voltage limit of 600 volts, the manufacturer or power supplier or both should be consulted to assure proper application.

f) Utilization equipment does not generally operate directly at these voltages. For equipment supplied through transformers refer to limits for nominal system voltage of transformer output.

g) For these systems, Range A and Range B limits are not shown because, where they are used as service voltages, the operating voltage level on the user's system is normally adjusted by means of voltage regulators to suit their requirements.

h) Standard voltages reprinted from American National Standard C92.2-1981 for convenience only. Reference this standard for more detailed information.

i) Nominal utilization voltages are for low-voltage motors and control. See Appendix C in the full ANSI Standard for other equipment nominal utilization voltages (or equipment nameplate voltage ratings).

Causes of Voltage Variations

Steady state service voltages, designed to be within a certain range, are affected by many variables. These variables include such items as the following:

- Transmission system voltage requirements
- Step-down transformer voltage ratios including any tap setting used
- Step-down transformer impedance
- Load tap changing or regulator use and settings
- Equipment failure or improper operation
- Distribution circuit design and the customer location on the circuit
- Cyclical load patterns on the system and the addition of load by customers
- Application of voltage reductions during emergency conditions by the supplying utility.
- Capacitor bank switching
- Circuit switching that temporarily reconfigures the system due to maintenance or system outages.
- Shunt reactors
- Static Var Compensators

Recommendations

It is recommended that Atlantic City Electric & Delmarva Power design to the nominal system voltages ±5% in the Bay & New Castle Regions and ±4% in the Atlantic Region, except for EHV, as defined in ANSI C84.1-1989. It should be noted that the minimum service voltages defined by ANSI C84.1-1989 in some cases are -2.5%. In those cases, Atlantic City Electric & Delmarva Power will continue to design to a minimum voltage as stated above.

TRANSIENT AND SHORT DURATION VOLTAGE VARIATIONS

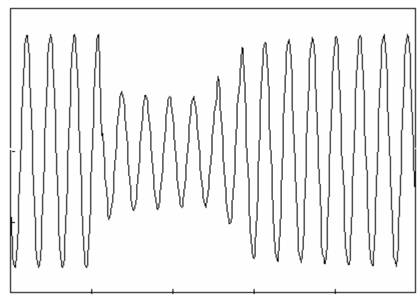
Definition

The following terms are selected as being the most important for discussing power quality phenomena. Electricity is normally generated, transmitted, and delivered to the customer as a 60 Hz sinusoidal wave. The term "power quality" broadly refers to maintaining the near sinusoidal voltage waveform at rated voltage magnitude and frequency. Some examples of basic voltage variations which alter the sinusoidal wave follow:

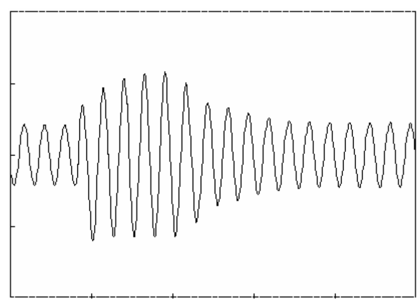
Transient — A sub-cycle disturbance in the ac voltage which is evidenced by a sharp brief discontinuity of the waveform. May be of either polarity and may be additive or subtractive from the normal voltage waveform.

Short Duration Variations

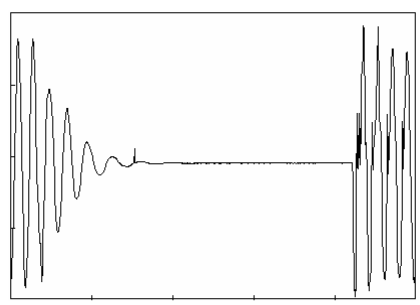
Sag — A decrease in the voltage or current, at the power frequency, for durations from 0.5 cycle to 1 minute.[18].



Swell — An increase in rms voltage or current at the power frequency, for durations from 0.5 cycle to 1 minute[18].



Interruption — The complete loss of voltage for a period of time:
Momentary (0.5 cycles - 3 seconds)
Temporary (3 seconds to 1 minute)
Sustained (>1 minute).



Harmonics — Harmonics are voltages or currents with frequencies that are integer multiples of the fundamental power frequency of 60 Hz. For example, if the fundamental frequency is 60 Hz, then the second harmonic is 120 Hz, the third is 180 Hz, etc.

Table 5.1

Categories and Typical Characteristics of Power System Electromagnetic Phenomena

CATEGORIES	SPECTRAL CONTENT	TYPICAL DURATION	TYPICAL MAGNITUDES
1. Transients			
Impulsive			
Nanosecond	5 ns rise	< 50 ns	
Microsecond	1 µs rise	50 ns - 1 ms	
Millisecond	0.1 ms rise	> 1 ms	
Oscillatory			
Low Frequency	< 5 kHz	.3 - 50 ms	0 - 4 pu
Medium Frequency	5 -500 kHz	20 µs	0 - 8 pu
High frequency	0.5 - 5 Mhz	5 µs	0 - 4 pu
2. Short Duration Variations			
Instantaneous			
Sag		0.5 - 30 cycles	0.1 - 0.9 pu
Swell		0.5 - 30 cycles	1.1 - 1.8 pu
Momentary			
Interruption		0.5 cycles - 3 s	< 0.1 pu
Sag		30 cycles - 3 s	0.1 - 0.9 pu
Swell		30 cycles - 3 s	1.1 - 1.4 pu
Temporary			
Interruption		3 s - 1 min	< 0.1 pu
Sag		3 s - 1 min	0.1 - 0.9 pu
Swell		3 s - 1 min	1.1 - 1.2 pu
3. Long Duration Variations			
Interruption, Sustained		>1 minute	0.0 pu
Undervoltage		>1 minute	0.8 - 0.9 pu
Overvoltage		>1 minute	1.1 - 1.2 pu
4. Voltage Imbalance		steady state	0.5 - 2%
5. Waveform Distortion			
DC Offset		steady state	0 - 0.01%
Harmonics	0 - 100th H	steady state	0 - 20%
Inter-Harmonics	0 - 6 kHz	steady state	0 - 2%
Notching		steady state	
Noise	broad-band	steady state	0 - 1%
6. Voltage Fluctuations	< 25 Hz	intermittent	0.1 - 7%
7. Power Frequency Variations		< 10 s	

Causes

Transients and short duration voltage variations can result from events, which occur on the utility system, or within the customer's facility, or as a result of the electrical parameters of the combined system. In general there are two classes of disturbances, which may effect the operation of sensitive electronic equipment, those which are conducted and those which are radiated. For the purposes of this discussion, only conducted disturbances will be considered. It is worthy of note that these disturbances, like all electrical phenomena, obey the basic laws of physics and thus the location of the revenue meter has no specific consequence in their analysis. The following list indicates events that generate conducted disturbances which may disrupt the operation of sensitive electronic equipment:

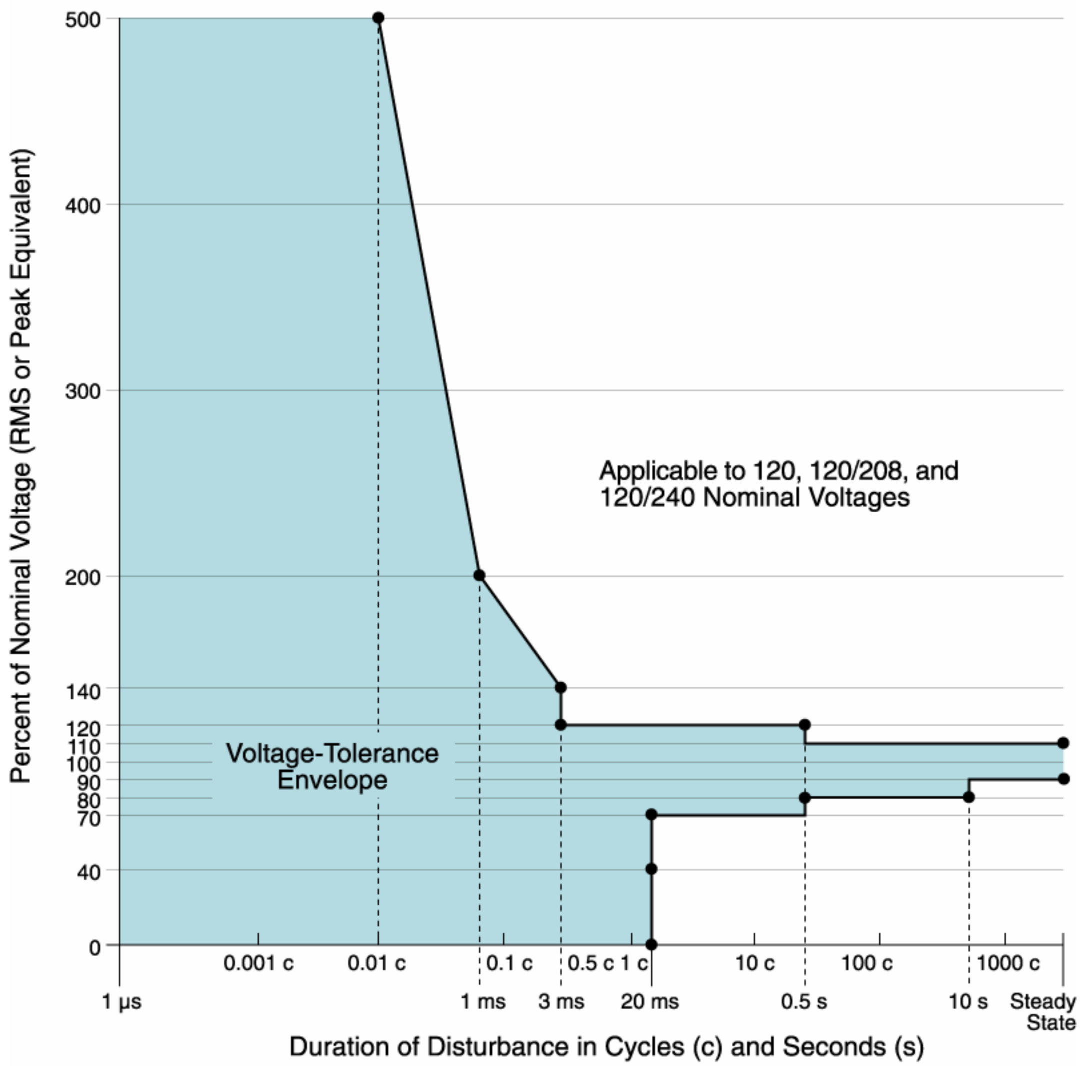
- Load switching
- Faults or short circuits
- Capacitor bank switching
- Arcing or loose connections
- Motor starting/stopping
- Operation of Silicon Control Rectifier (SCR) devices
- Operation of rectifier type loads
- Inappropriate wiring or grounding practices
- Lightning
- Solar Magnetic Disturbances

Effects

The increased use of computer technology for process control and business operations has begun to change the utility customer's perception of quality electric service. The ability to tolerate the impact of transients and voltage variations frequently depends on a variety of factors including the criticality of the function or process, the design and configuration of the power system supplying the critical load, and the design of the critical load itself.

Out of a concern for developing industry accepted operating criteria, the Computer Business Equipment Manufacturers Association (CBEMA) has adopted an equipment tolerance envelope. This set of curves (Figure 5.3[2]) illustrates typical design goals for the power conscious computer manufacturer.

CBEMA Curve



Revised 1996

Figure 5.3 "Safe" Operating Envelope for Computer Power

Appendix A provides an excerpt from ANSI/IEEE Std. 446-1987 which gives a partial description of voltage variations based on their duration. It should be noted that since this book was written in 1987, advances have been made in industry accepted terminology. For that reason, some of the terms as well as the time divisions used in this excerpt, differ from those discussed above. The concepts, however, are of value. It is readily apparent from a comparison of these disturbances with Figure 5.3, why some affect equipment operation while others do not.

The net effect of these transients and voltage variations at the point of end use, can be damaged equipment, lost productivity or inconvenience. The effects have increased utility customers' sensitivity and awareness of the existence of such disturbances. In many cases, even though the utility is not the source of the disturbance, since it is electric power related, it is perceived as an electric utility problem.

The industry, including utilities, equipment manufacturers, and end users, are only now beginning to address the issue of compatibility between customer equipment and the power source.

Recommendations

Atlantic City Electric & Delmarva Power should respond promptly to all customer concerns about transients and voltage variations. Because the causes and consequences of these phenomena are so diverse, there is no universal solution for these problems. Atlantic City Electric & Delmarva Power, however should work with the customer using mutual discussion, outage records, observation, and recording instrumentation to identify the nature and source of the disturbance and recommend possible solutions. See Power Quality Procedures below.

FLICKER

Definition

For many decades "voltage flicker" or "lamp flicker" has been defined as a perceptible change in the light output of incandescent lamps produced by chronic repetitive sudden changes in supply voltage. Most often the transient voltage causing flicker persists for a number of cycles or longer.

Traditionally two levels of flicker have been defined.[3] One is designated "minimum threshold of perception" or "borderline of visibility". The other is designated "tolerance threshold" or "borderline of irritation." Studies were conducted many years ago to measure the reaction of a large number of people to changes in light intensity produced by voltage fluctuations of various magnitudes and frequencies of occurrence. Curves were then plotted showing the two "borderlines" and how annoyance is effected by changes in the above two parameters (See Figure 6.1).

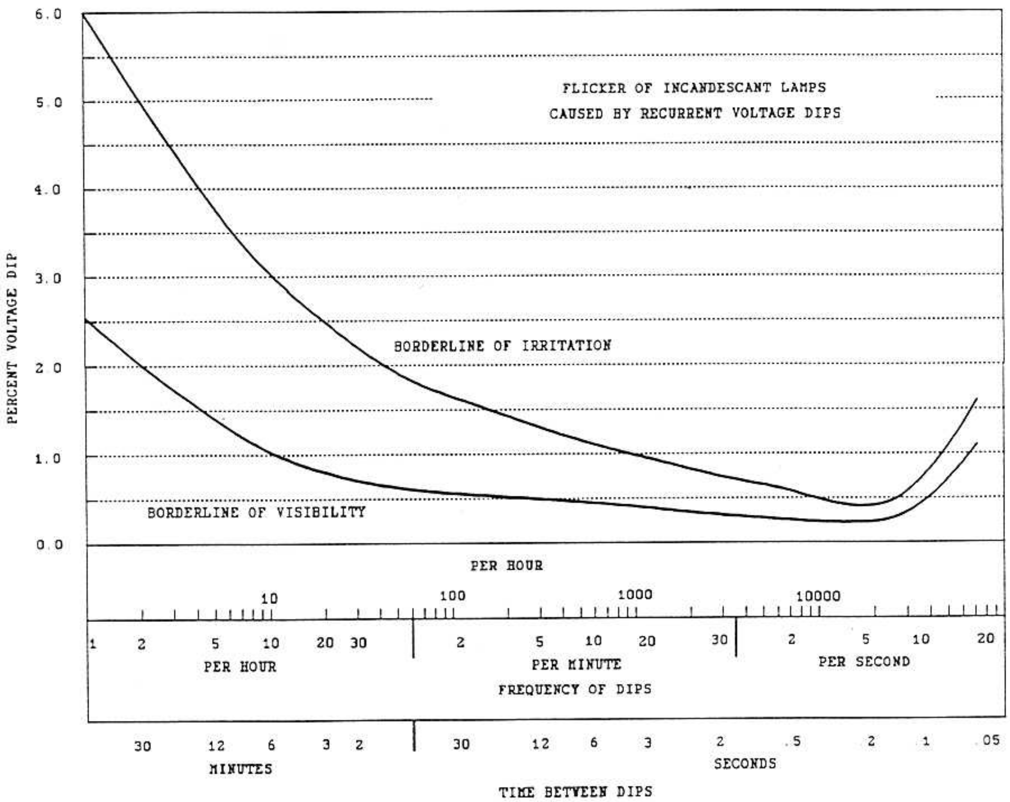


Figure 6.1 Flicker Annoyance Levels

Causes

Flicker may be created by a variety of conditions on the power supply system. Motor starting, heavy intermittent loads such as arc-welders, arc furnaces and spot welders, and loose connections are common sources of flicker.

Effects

Rapid changes in voltage create corresponding changes in light output. These changes are most readily perceived in incandescent lamps.

The net effect of this flicker then most often becomes a human psychological objection to the perceived discomfort caused by it. Most often this objection manifests itself in a real concern about fire or physical hazards. Some sources generate flicker that is perceived only at the customer’s site where it is produced while others may effect nearby customers.

Recommendations

Because of the wide variation in individual response to a given level of flicker it then becomes necessary to define a reasonable level of flicker above which corrective action is necessary.

Defining a "tolerance threshold" is desirable from a utility standpoint, because it establishes a reasonable level of service and influences the design, operation, and maintenance of an electrical system.

The level of flicker that Atlantic City Electric & Delmarva Power defines as acceptable for normal system operation is the "Borderline of Irritation" as described by the curve of Figure 6.1. This curve is being used by nearly 70% of utilities responding to a 1985 IEEE survey for this same purpose.[5] Atlantic City Electric & Delmarva Power will initiate corrective action or advise the customer to do so for flicker above the Borderline of Irritation level. Flicker below this threshold, resulting in customer dissatisfaction, will be investigated on a case-by-case basis and corrective action may be taken.

HARMONIC DISTORTION

Definition

Harmonics Any periodic waveform can be described mathematically as a series of sinusoids summed together as is illustrated in Figure 6.1. The sinusoids are integer multiples of the fundamental periodic cycle, which vary in magnitude and phase angle. Each term in the series is referred to as a "harmonic" of the fundamental frequency. The term having the same frequency as the fundamental is the first harmonic and is also referred to as simply the fundamental. The term having twice the fundamental frequency is the second harmonic, and so on. Figure 7.1 below illustrates the sum of the fundamental, 3rd, 5th, 7th and 9th harmonics of varying magnitudes to form an approximate square wave.

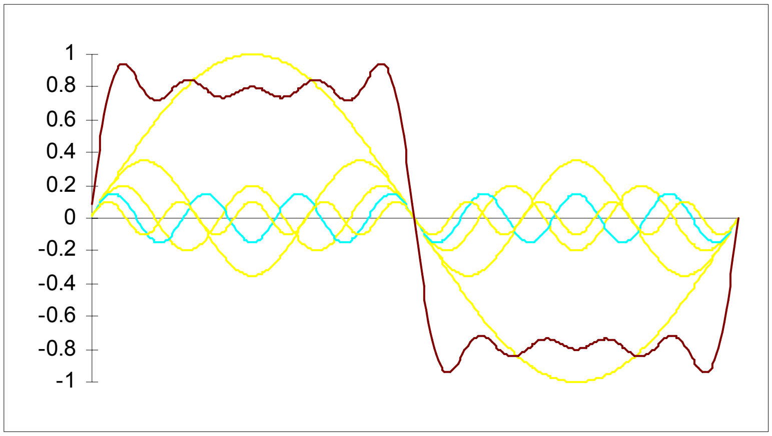


Figure 7.1 Harmonic Components of a Square Wave

Harmonic Distortion

The more harmonics present in a waveform the more "distorted" that waveform becomes when compared to the pure fundamental sinusoid. The following terms, expressed in percent distortion, are frequently used to quantify the level of harmonics present in a particular system.

Individual Harmonic Distortion

This term is used to quantify the magnitude of a single harmonic frequency voltage or current in the power system. It is expressed as a ratio of the RMS value of a single harmonic frequency quantity to the RMS value of the fundamental.

$$\frac{I_h(RMS)}{I_1(RMS)} \times 100\% \quad \text{or} \quad \frac{V_h(RMS)}{V_1(RMS)} \times 100\%$$

Total Harmonic Distortion (THD)

Total harmonic distortion is used to quantify the total magnitude of harmonics present in the power system voltage waveform. It is expressed as a percent of the fundamental voltage and is defined as:

$$THD = \sqrt{\frac{Sum\ of\ Squares\ of\ Amplitude\ of\ all\ Harmonic\ Voltages}{Square\ of\ Amplitude\ of\ Fundamental\ Voltage}} \times 100\%$$

or

$$THD = \frac{\sqrt{Sum\ of\ Squares\ of\ RMS\ Value\ of\ all\ Harmonic\ Voltages}}{RMS\ Value\ of\ Fundamental\ Voltage} \times 100\%$$

Harmonics from 2 through 50 times fundamental frequency are normally considered.

Total Demand Distortion (TDD)

Total demand distortion is used to quantify the total magnitude of harmonics present in the power system current waveform. It is expressed as a percent of the fundamental frequency maximum demand load current (15 or 30 minute demand interval) and is defined as:

$$TDD = \frac{\sqrt{Sum\ of\ Squares\ of\ RMS\ Value\ of\ all\ Harmonic\ Currents}}{RMS\ Value\ of\ Fundamental\ Frequency\ Maximum\ Demand} \times 100\%$$

Harmonics from 2 through 50 times fundamental frequency are normally considered.

Causes

In a power system, harmonic distortion is caused by non-linear elements in circuits. Non-linear elements are characterized by a relationship in which voltage is not proportional to current. This relationship results in a waveform that becomes non-sinusoidal and thereby generates harmonics on the system.

In the power system, this non-linear load can be represented as a load to the 60 Hz (fundamental) component of current and as a source of current for the harmonic current components. These harmonic currents, generated at the non-linear load, flow toward the source of the fundamental through the paths of least resistance. The voltage distortion experienced by the fundamental is a function of the voltage drops in components of the power system at the harmonic frequencies as these harmonics flow through the power system.

In a power system almost all of the series impedances are linear. These impedances consist of lines, cables, and transformers. Nonlinear elements are normally connected in shunt with the power system. Transformers are a special case because they have both linear and nonlinear characteristics. The short circuit impedance (series impedance) is linear whereas the magnetizing impedance which is a shunt impedance is non-linear. Generators also produce harmonics but they are generally negligible. For the most part, harmonic production on a utility power system comes from loads connected to the system or specialized switching equipment. This specialized equipment can be Static Var Compensation (SVC) or High Voltage Direct Current (HVDC) line terminals.

There are three major classes of equipment that inject harmonics into the power system:

- Ferromagnetic Devices
- Electronic Power Converters
- Arcing Devices

Ferromagnetic Devices are most commonly represented by transformer and motors connected to the power system. A motor's magnetic characteristic is generally linear because of the air gap in the motor. A transformer's magnetizing current characteristic is very non-linear which results in a third harmonic about 50% of the fundamental. Delta windings reduce the magnitude of the third and ninth harmonics injected into the system. The fifth and seventh harmonics then become prevalent. Since a transformer's excitation current is 0.5% to 1.0% of the rated load current, harmonic injection contributions from transformers are generally not a problem. However, because of the large number of transformers on a power system, harmonic current injections can become significant. As applied voltage increases, such as during light load periods, saturation also increases thereby further contributing to harmonic current injection.

Electronic Power Converters can include rectifiers, inverters, adjustable speed motor drives, and light dimmers. Most of these types of equipment are dependent on the power system waveform to turn the thyristors or diodes in these devices off after they begin conducting. This is referred to as line commutation. The total harmonic distortion in the current waveform of line commutation devices is typically 10% to 30% of the load current. Devices that are force commutated switch the flow of current on or off at will. These devices can be designed to generate waveforms that do not contain problem harmonics.

The most common electronic power converters are single phase, fullwave rectifiers typically found in appliances and computers. The dominance of a third harmonic, which can be as high as 50% of the fundamental load current, has been documented by relating television viewing times to primary feeder voltage distortion.

Arcing devices include fluorescent lighting, sodium and mercury vapor lighting, electric arc furnaces, and electric arc welders. All these devices generate similar harmonic current injections. Electric arc furnaces have created the most harmonic problems because of the magnitude of the load that is concentrated at one point on the power system. Lighting presents a greater load but because the load is spread out across the system, the impact of the harmonics generated is reduced.[7]

Balanced three phase devices generally eliminate the third and ninth harmonics. This does not apply to arc furnaces since during scrap meltdown, the load is extremely erratic and unbalanced. Even harmonics are also found in electric arc furnaces due to erratic arcing that results in unequal conduction of current during positive and negative half cycles.

Effects

The effects of harmonics producing loads on Atlantic City Electric & Delmarva Power equipment and on other Atlantic City Electric & Delmarva Power customers are greatly dependent on the system characteristics. The fact that a load has a distorted current waveform is not a definite indication that there will be an adverse impact to either the power system or other power consumers. Power systems are capable of absorbing considerable harmonic currents without noticeable problems. Many of the problems have involved resonance resulting from the size and location of a nearby capacitor bank. Harmonic resonance can amplify voltage distortion and cause capacitor bank failure. Harmonic distortion can result in watt-hour meter error and cause interference in communication circuits.[7] In the case of watt-hour meters, the error is generally slight. When considering the effects of a harmonic producing load on other utility customers, the voltage distortion is the primary concern. The presence of a significant harmonic current does not mean that there will be significant voltage distortion. If the source impedance is low, the voltage distortion will be low and the other customers will be unaffected.

Most commonly, electronic equipment produces 3rd, 5th and 7th harmonic currents. When sufficient levels of these currents are present, adverse effects such as nuisance circuit breaker tripping, transformer and neutral conductor overheating, and capacitor fuse operations can be experienced. These symptoms typically occur on the customer’s low voltage system before they effect the utility distribution system.

Although the harmonic currents do not directly affect other power consumers if the voltage distortion is low, they may have detrimental effects on other power system elements such as generators and transformers. Also, harmonic currents may be coupled to other electrical circuits such as communications that are in parallel with the power circuits. A power system may incur increased losses in transformers and generators. If the harmonic content is high enough, hot spots may develop which can result in insulation failure. Generally, current distortion seen by substation transformers and generators is small in relation to the total power system load which is linear or non-harmonic producing.

However, if the use of electric power converters continues to increase, such as adjustable speed motor drives for residential heat pumps, this may not be the case sometime in the future.

Recommendations

Atlantic City Electric & Delmarva Power should use IEEE Standard 519, "Recommended Practices and Requirements for Harmonic Control in Electric Power Systems" as a guide for controlling harmonics in the electrical system and as a reference for solving problems that may arise in terms of objectionable harmonics encountered in the system.

This industry standard describes the quality of electrical power that a utility should furnish the consumer in regard to harmonic distortion of the voltage waveform. It also describes the harmonic current injection limits that should apply to individual consumers of electrical energy. These recommendations were established with the goal of minimizing harmonic interference problems among both the utility and customer systems.

IEEE 519 refers to the Point of Common Coupling (PCC) as the point at which the customer interfaces with the utility and other users. This may be a metering point or point of service.

Table III shows the harmonic voltage limits that are recommended at the PCC defining the quality of voltage to be delivered to the customer by Atlantic City Electric & Delmarva Power.

Table III Harmonic Voltage Distortion Limits

Bus Voltage at PCC	Individual Harmonic Voltage Distortion (%)	Total Voltage Distortion THD (%)
Below 69 kV	3.0	5.0
69kV to 138 kV	1.5	2.5
138 kV and above	1.0	1.5

Note: High voltage systems can have up to 2.0% THD where the cause is an HVDC terminal that will attenuate by the time it is tapped for a user.

Tables IV, V, and VI show the harmonic current limits that are recommended to be the maximum harmonic current injections permitted into the Atlantic City Electric & Delmarva Power system at the PCC by a customer.

For shorter periods of time (less than one hour), during startups or unusual conditions, the limits may be exceeded by 50%.

The harmonic current limits are based on the size of the load with respect to the size of the power system to which the load is connected. The ratio I_{SC}/I_L is the ratio of the short circuit current available at the point of common coupling (PCC), to the maximum fundamental load current. It is recommended that the load current I_L be calculated as the average current of the maximum demand for the preceding twelve months. Thus as the size of the user load decreases with respect to the size of the system, the larger is the percentage of harmonic current the user is allowed to inject into the utility system. This protects other users on the same feeder as well as the utility which is required to furnish a certain quality of power to its customers.

Table IV. Harmonic Current Limits for Systems 120 Volts Through 69 kV

Maximum Harmonic Current Distortion in % Fundamental						
Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	**<11**	**11$\leq$h<17**	**17$\leq$h<23**	**23$\leq$h35**	**35$\leq$h**	**TDD**
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.
Current distortions that result in a direct current offset, e.g., half wave converters are not allowed.
*All power generation equipment is limited to these values of current distortion regardless of actual I_{SC}/I_L.
Where I_{SC} = Maximum short circuit current at PCC
and I_L = Maximum demand load current (fundamental frequency) at PCC

Table V. Harmonic Current Limits for Systems 69 kV Through 161 kV

Maximum Harmonic Current Distortion in % Fundamental						
Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	**<11**	**11≤h<17**	**17≤h<23**	**23≤h35**	**35≤h**	**TDD**
<20*	2.0	1.0	0.75	0.3	0.15	2.5
20<50	3.5	1.75	1.25	0.5	0.25	4.0
50<100	5.0	2.25	2.0	0.75	0.35	6.0
100<1000	6.0	2.75	2.5	1.0	0.5	7.5
>1000	7.5	3.5	3.0	1.25	0.7	10.0

Even harmonics are limited to 25% of the odd harmonic limits above.
*All power generation equipment is limited to these values of current distortion regardless of actual I_{SC}/I_L.
Where I_{SC} = Maximum short circuit current at PCC
and I_L = Maximum demand load current (fundamental frequency) at PCC

Table VI. Harmonic Current Limits for Systems above 161 kV and Privately Owned Generation at any Voltage Level

Maximum Harmonic Current Distortion in % Fundamental						
Harmonic Order (Odd Harmonics)						
I_{SC}/I_L	**<11**	**11≤h<17**	**17≤h<23**	**23≤h35**	**35≤h**	**TDD**
<50	2.0	1.0	0.75	0.3	0.15	2.5
□50	3.0	1.5	1.15	0.45	0.22	3.75

Even harmonics are limited to 25% of the odd harmonic limits above.

If the above recommended limits are exceeded or specific harmonic problems arise certain measures should be undertaken to identify and correct such occurrences. These measures may include:

- Performing harmonic measurements at selected points within the utility system including PCC's and attempt to determine sources of harmonic current injection. If the defined limits identified in this guideline are exceeded, then such measures as necessary should be taken to assure compliance (i.e., installing filters, static var compensators, reducing harmonic generation sources, etc.).

- Modifying the source impedance to allow the system to absorb more harmonics.

- Isolating the harmonic load on separate supply circuits.

PHASE VOLTAGE UNBALANCE IN THREE PHASE SYSTEMS

Definition

Several methods have been proposed to quantify the amount of phase voltage unbalance of a polyphase system, however the most generally accepted definition as presented by ANSI [9] & NEMA [10] is:

$$\%Voltage\ Unbalance = \frac{(Max\ Deviation\ from\ Avg\ Voltage)}{(Average\ Voltage)} \times 100$$

Example: With phase-to-phase voltages of 230 v, 232 v, and 225 v, the average is 229 v: the maximum deviation from average is 4 v; and the percentage unbalance is
100 x 4/229 = 1.75%.

This simplified method of calculation avoids the need to calculate actual negative sequence voltages or currents, which are the major cause of motor over-heating resulting from phase unbalance. (See Effect of Phase Voltage Unbalance)

Studies have demonstrated that for all practical purposes the magnitude of unbalance voltage in percent, calculated from the equation above, and the actual negative sequence voltage in percent, are essentially equal.

Causes

Certain events such as system faults, blown fuses, and open conductors can cause severe unbalance conditions to exist on the power system. These occurrences are considered abnormal and are beyond the control of the electric utility. However, continuous levels of unbalance caused by the diversity of single phase load on the three phase system can and must be controlled so as to ensure proper operation of connected equipment.

"Most utilities use four wire grounded wye primary distribution systems so that single phase distribution transformers can be connected phase to neutral to supply single phase load such as residences and street lights. Variations in single phase loading cause the currents in the three phase conductors to be different, producing different voltage drops and causing the phase voltages to become unbalanced. Normally the maximum phase voltage unbalance will occur at the end of the primary distribution system, but the actual amount will depend on how well the single phase loads are balanced between the phases on the system.

Perfect balance can never be maintained because the loads are continually changing, causing the phase voltage unbalance to vary continually."[12]

Effects

Phase Voltage Unbalance

Phase voltage unbalance can affect the operation of various types of electrical equipment, however, the most prevalent being polyphase induction motors.

Performance of polyphase induction motors under unbalanced voltage conditions is discussed in NEMA MG 1-1993:

"When the line voltages applied to a polyphase induction motor are not equal, unbalanced currents in the stator windings will result. A small percentage voltage unbalance will result in a much larger percentage current unbalance. Consequently, the temperature rise of the motor operating at a particular load and percentage voltage unbalance will be greater than for the motor operating under the same conditions with balanced voltages.

The effect of unbalanced voltages on polyphase induction motors is equivalent to the introduction of negative sequence voltage having a rotation opposite to that occurring with balanced voltages. This negative sequence voltage produces in the air gap a flux rotating against the rotation of the rotor, tending to produce high currents. A small negative sequence voltage may produce in the windings currents considerably in excess of those present under balanced voltage conditions.

The locked-rotor torque and breakdown torque are decreased when the voltage is unbalanced. If the voltage unbalance should be extremely severe, the torques might not be adequate for the application.

The full-load speed is reduced slightly when the motor operates at unbalanced voltages.

The locked-rotor current will be unbalanced to the same degree that the voltages are unbalanced but the locked-rotor kVA will increase only slightly.

The currents at normal operating speed with unbalanced voltages will be greatly unbalanced in the order of approximately 6 to 10 times the voltage unbalance."[10]

The rated load capability of polyphase equipment is normally reduced by voltage unbalance. A common example is the derating factor, shown in Fig. 8.1 in tabular form, used in the application of polyphase induction motors to reduce the possibility of damage due to over-heating. (See Section 14.35 of NEMA MG1-1993 for more complete information.)

	Percent Voltage Unbalance										
	0.0%	0.5%	1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
Derating Factor	1.00	0.99	0.98	0.97	0.96	0.93	0.90	0.87	0.84	0.79	0.76

Figure 8.1 Derating Factor

Other equipment, including such electronic devices as computers may also be affected by phase voltage unbalance. Individual equipment manufacturers should be consulted for necessary information regarding performance under unbalance conditions.[12]

Phase Current Unbalance

By restricting voltage unbalance, the Atlantic City Electric & Delmarva Power supply system can be held to a quantifiable level of service voltage quality which can be expected by its customers. Although not a quality of service issue, current unbalance must also be controlled due to its detrimental effects on rotating equipment.

Of particular interest when discussing phase current unbalance in polyphase systems is the effect of such a condition on generators. An unbalanced system can be represented by balanced positive, negative, and zero phase sequence components. It is the negative phase sequence current which has a detrimental effect on the rotating equipment.

"The negative sequence current (I_2) flows in the stator windings producing a magnetic flux that has the same rotational speed as the rotor flux but in the opposite direction. This flux is cut by the rotor at twice the rotational speed, and induces rotor currents at double the system frequency. These high frequency eddy currents flow in the rotor surface iron, brass slot wedges and retaining rings resulting in the heating of the rotor surface.

The effect of this heating is dependent on the negative sequence current and the duration of exposure. Sustained high levels of negative sequence current can soften brass slot wedges to the point of being extruded by centrifugal force until they stand out from the rotor and strike the stator. Less severe heating reduces the generators useful life by accelerating the deterioration of the insulation."[13]

ANSI C50.12-1982, C50.13-1989, and C50.14-1977 specify the required I_2 ratings for various types of generators. The short-term rating, generally expressed as $(I_2)^2t$, is of concern when considering the effects of faults on the generator. The protection of generators for excessive I_2 created by the unbalance due to faults is provided by applying appropriate relays in the generator protective relay schemes.

ANSI C50.13-1989 states: "A generator shall be capable of withstanding without injury the effects of a continuous current unbalance corresponding to a negative phase sequence current of the following values, providing the rated kVA is not exceeded and the maximum current does not exceed 105 percent of rated current in any phase."[14] Negative phase sequence current is expressed as a percentage of rated stator current.

Type of Generator	Permissible I_2 (Percent)
Cylindrical rotor generators[14]	
Indirectly cooled	10
Directly Cooled to 960 MVA	8
961 to 1200 MVA	6
1201 to 1500 MVA	5
Salient pole synchronous generators and generator/motors for hydraulic turbine applications[16]	
Machines with connected amortisseur windings	10
*Machines with non-connected amortisseur windings	5

*It should be noted that continuous performance with non-connected amortisseur windings is not readily predictable. Therefore, if unbalanced conditions are anticipated, machines with connected amortisseur windings should be utilized.

Recommendations

Consistent with ANSI C84.1-1989, Atlantic City Electric & Delmarva Power shall design and operate its system to limit the maximum steady state voltage unbalance to 3% at our delivery point under no load conditions. Expectations are that the customer's load must be reasonably well balanced resulting in no appreciable voltage unbalance increase under full load. In some cases, restrictions may be imposed on the connection of "large" single phase loads which would cause the voltage unbalance of the supply system to exceed 3% or which would cause the negative sequence current of any interconnected generator to exceed 10% of its rated stator current. When voltage unbalances in excess of 3% are found, local load balance shall be measured to determine the cause. Under specific conditions, the following actions will be taken.

- If local loads are reasonably balanced, Atlantic City Electric & Delmarva Power will analyze its system to determine the cause and correct it.
- If an unbalanced customer load is the cause, but the resulting condition only affects that one customer, Atlantic City Electric & Delmarva Power will notify the customer of the condition and recommend corrective action.
- If the load unbalance of one customer affects the voltage of other customers adversely, Atlantic City Electric & Delmarva Power will require that the customer correct the problem.

It is the customer's responsibility to install appropriate unbalance limit controls to protect their equipment from open phase conditions or other severe voltage or current unbalance conditions which may be hazardous to their equipment.

Power Quality Procedures

District Engineering Receives Customer Complaint

The customer complaint may come into District Engineering from a variety of sources – Call Center, Marketing, Consultant, Customer, etc.

Initial Investigation

District Engineering promptly contacts the customer to determine the nature of the complaint. If the customer's concern requires further investigation as a power quality issue, then a Power Quality Questionnaire should be completed. This may be completed over the phone if the customer has the time or mailed out to the customer for completion.

The timing and priority of the response shall depend upon the nature of the complaint made, the alleged effect of the power quality issue or the customer's service, whether any safety issues have been raised or known by the Company, and the engineering judgement of the District Engineering personnel assigned to handle the complaint.

For large power accounts, the major accounts representative should be kept informed of the situation.

For radio or TV interference, contact the appropriate Electrical Maintenance Group to investigate the situation.

Power Quality Questionnaire

The questionnaire is a useful tool in assessing the customer's concern. It should be filled out as completely as possible. The Case Number is intended to be unique to each District. The number should include the District Name, the year and the case number. For example: The 12th customer inquiry in 1999 for the Winslow District would have a case number of Winslow - 99 – 12. Each District should keep a log of all questionnaires completed. The questionnaires and resulting investigation data could be used as a basis for future system improvement projects.

Develop Investigation Plan

The plan for conducting a power quality investigation should be well thought out and provide an outline for conducting the investigation. The plan should be flexible and allow for change as new data and information is gathered during the inspection and monitoring portions of the survey. The plan also serves to gain commitment for both personnel and equipment. It is a plan as to what is to be done, when, and by whom, equipment and resource requirements, and expected results.
The scope of activities should determine if power quality monitoring equipment is needed and, if so, what should be monitored. In developing the scope of activities, it may be necessary to preview the site prior to completing the plan.

Support or Assistance

If support or assistance is needed, contact Distribution Design, System Protection, Distribution Assets, or a Power Quality Contractor.

Investigate and Determine Source of Problem

The investigation typically is composed of several activities. A visual and physical inspection of our equipment and the customer's equipment is required. When on the customer's premises use extreme caution around the customer's equipment, having the customer or the customer's electrician remove panel covers and other access panels. Install monitoring equipment as appropriate.

Submit Report to Customer with Recommended Solution

Prepare a detailed report in conjunction with the involved PQ specialist noting the nature of the customer's concern, results of the investigation, and the recommended solution. The recommended solution should be clear as to what Atlantic City Electric & Delmarva Power and the customer should do to resolve the problem. Present the report to the customer after the District Supervisor of Planning & Design approves and signs the report.

After customer agrees with the work needed, issue work order to complete the required work to Atlantic City Electric & Delmarva Power's plant. Determine when the customer might complete any necessary work to their equipment.

Follow-up with the customer(s) after the recommended work is complete to see if the customer is now satisfied.

Appendix A

From ANSI/IEEE STD 446-1995

Short Duration Disturbances

Most disturbances on a power system are of short duration. Studies show that 90% are less than one second. Voltage disturbances of more than one cycle duration are usually expressed in rms values. Those of less than one cycle are expressed in terms of the fundamental peak value.

Less Than 1 Cycle – Transient

Transients result from disturbance of all kinds. The most severe subcycle disturbances are natural lightning, electrostatic discharge, load switch, and short-duration faults.

Half Cycle to a Few Seconds – Swell or Sag

Swells (increased voltage) or sags (decreased voltage) usually result from faults on the system with subsequent fuse or high speed circuit breaker action and reclosing. On the loaded phases this results in a sag, on the unloaded phases the result may be a swell.

More Than a Few Seconds – Overvoltage or Undervoltage

Overvoltage and undervoltage, usually attributed to severe faults accompanied by 50-100% voltage loss on one or more phases, often result in an outage in some circuit. Faults often involve all three phases and may be the result of a downed pole, a tree, or a crane on the line, a breaker lockout, or an in-line fuse blowing. If the critical load is on the cleared side of the fuse, the disturbance becomes an outage. If it is on the power source side of the fault clearing device, the normal voltage may be restored.

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Power Quality Questionnaire

Case ________________________________

Date:_________________________________

ACE/DPL Phone:__________________________ Representative:______________________________

Customer:____________________________________ Account #:______________________________

Company:____ Res. / Comm. / Ind.

Address:____

City:__________________________________ State:_________ Zip Code:______________________

Contact:____ Phone:________________________

Contact:____ Phone:________________________

Site Description:____ Age of Site:____________

Transformer Size:_____________ kVA Voltage:________________________ POLE / PAD

Transformer Coordinate Number:_____________/______________ Circuit Number:_______________

Service Size:____ Length:_______________ feet

1. Description of Problem (include dates & times; Equipment affected)

2. Trouble / Serviceman been to site? Yes / No Work Order / TT#:_____________________
Remarks:

3. Why does the customer think the disruption is due to power disturbances?

____Operator error ruled out or not considered likely
____Equipment failure for non-power reasons ruled out
____Wiring / ground verification completed
_____Surge / transient protection survey completed
_____Power monitoring data available from customer
_____Customer / consultant investigated problem

____Other:____

4. What are the symptoms of the problem?

____Lights off or blinking
____Loss of power for extended periods
____Known harmonic or phone problems
____System lock-ups or random computer re-boots
____Stops or unready lamps lit
____Machine resets

Line recloser before customer: Yes / No
Recent outages: Yes / No
Capacitor bank on feeder Yes / No
____Errors / Data loss
____Inconsistent results
____Electronic equipment problems

____Other:____

5. Has there been equipment or product damage? Yes / No

____Circuit breakers tripped
____Transformers overheated
____Arcing or evidence of flashover
____Circuit breakers overheated
____Charred insulation or burned areas

____Other:____

6. Frequency and duration. (Enter a number next to one of the following):

______per day ______per month ______per quarter _____per year

7. How long are operations disrupted during a typical occurrence?________________________

8. Does the problem occur at a specific time of day or work shift? Yes / No
If Yes, specify when and with what regularity, including other activities with which the problem
correlates:

9. Is the problem associated with any unusual weather conditions? Yes/ No

10. Have any of the following been done on the system (unrelated to the problem) by contractors or the customer's facility engineers?

____New work
____Changes
____Additions

Describe:____
_
_

11. What has the customer done towards solving the problem?

____Hired a consultant
____Conducted a wiring/grounding verification
____Installed wiring/grounding retrofit
____Installed power conditioning equipment
____Hired an electrical contractor
____Monitored power
____Installed surge/transient protection retrofit

Other:____

12. Other relevant information:

Is a Power Quality Investigation recommended? Yes / No

Record recommendations made to customer and/or company action taken:________________

Completed By:____ Date:____________________

Power Quality Plan of Action

I Physical Inspection Safety Always - Wear Your Personal Protective Equipment

1. Tour the plant examining all electrical equipment.
2. Determine how the equipment is electrically connected / fed.
3. Determine exactly what equipment is affected.
4. Determine how the affected equipment is electrically connected / fed.

    - ❑ Straight feed from the panel board.
    - ❑ Feed from electronic device (Example: Motor frequency drives)
    - ❑ Determine what other equipment is fed by same internal circuit.
    - ❑ Nominal service voltage
    - ❑ Equipment utilization voltage rating.

5. Check electrical conduits for mechanical connection and excessive warmth.

6. Inspect all associated electrical panelboards and record the following information and measurements:

Location: ____

Panelboard Number: ____

Manufacturer & Model Number: ____

Type / Rating: ____

Pole Positions: ____

Phase Amperage: ____

Neutral Amperage: ____

Ground Bus: ____

Isolated Ground Bus: ____

<u>Voltage Measurements</u>

A – N ____________ A – B ____________ A – G ____________

B – N ____________ B – C ____________ B – G ____________

C – N ____________ C – A ____________ C – G ____________

N – G ____________

Does any phase voltage vary 5% or more? * Yes _____ No _____

Does any phase to neutral voltage vary more than 2% from phase to ground voltages? ** Yes _____ No _____

Does neutral to ground voltage exceed 2 volts? *** Yes _____ No _____

<u>Current Measurements</u>

A ______________ B ______________ C ______________

N ______________ G ______________

Is the current for any conductor 80% or greater than the amperage rating of the wire or circuit breaker? Yes ______ No ______

Which wire or breaker position? (Note & mark for repair)

1 _____________	4 _____________	7 _____________	10 _____________
2 _____________	5 _____________	8 _____________	11 _____________
3 _____________	6 _____________	9 _____________	12 _____________

Are any ground currents excessive? Yes ______ No ______
Which wires? (Note & mark for repair)

1 _____________	4 _____________	7 _____________	10 _____________
2 _____________	5 _____________	8 _____________	11 _____________
3 _____________	6 _____________	9 _____________	12 _____________

Does the IR drop across any breaker exceed 0.1 volt? Yes ______ No ______

Does the temperature of any breaker exceed 40^0 C? Yes ______ No ______
Which breaker position? (Note & mark for repair)

1 _____________	4 _____________	7 _____________	10 _____________
2 _____________	5 _____________	8 _____________	11 _____________
3 _____________	6 _____________	9 _____________	12 _____________

Comments:

* Check cause of voltage variation
** Check transformer grounding and neutral
*** Check transformer neutral to ground bond

7. Inspect all transformers and record the following information and measurements.

Location ____

Transformer ____

Manufacturer ____

Impedance ____

Type ____

kVA ____

Voltage ____

Voltage Measurements

H1-G __________ X1-N __________ X1-X2 __________

H2-G __________ X2-N __________ X2-X3 __________

H3-G __________ X3-N __________ X3-X1 __________

X1-G __________ X0-N __________

X2-G __________ N0-G __________

X3-G __________

Does any phase voltage vary 5% or more? * Yes ______ No ______

Does any phase to neutral voltage vary more Than 2% from phase to ground voltages? ** Yes ______ No ______

Does neutral to ground exceed 0.2 volts? *** Yes ______ No ______

Current Measurements

H1 ____________________ N ________________________

H2 ____________________ G ________________________

H3 ____________________ X0 ________________________

X1 ____________________ X0 To Building ____________________

X2 ____________________ X0 To Enclosure ____________________

X3 ____________________

Observations

Does X0 to enclosure current exceed 2 amperes? Yes ______ No ______
(Larger current levels can mean wiring errors)

Does X0 current equal neutral current? Yes ______ No ______
(X0 current larger than neutral means wiring errors)

Is X0 reference a conductor? Yes ______ No ______
(Wire conductors are preferred)

Is safety ground conductor parity to phase conductors? Yes ______ No ______
(Parity conductor sizing is preferred)

Is safety ground parallel in power feeders? Yes ______ No ______
(NEC recommends symmetrical power feeders)

Comments: ____

____

____

* Check cause of voltage variation
** Check transformer grounding
*** Check transformer neutral to ground bond

8. Inspect service entrance and record the following information and measurements:

Location: ____

Panelboard Number: ____

Manufacturer & Model Number: ____

Type / Rating: ____

Pole Positions: ____

Phase Amperage: ____

Neutral Amperage: ____

Ground Bus: ____

Isolated Ground Bus: ____

Voltage Measurements

A – N ____________	A – B ____________	A – G ____________
B – N ____________	B – C ____________	B – G ____________
C – N ____________	C – A ____________	C – G ____________
		N – G ____________

Does any phase voltage vary 5% or more? * Yes ______ No ______

Does any phase to neutral voltage vary more than 2% from phase to ground voltages? ** Yes ______ No ______

Does any neutral to ground voltage exceed 0.2 volts? *** Yes ______ No ______

<u>Current Measurement</u>

A ____________ B ____________ C ____________

N ______________ G ______________

Is the current for any conductor 80% or greater than the amperage rating of the wire or circuit breaker? Yes ______ No ______

Which wire or breaker position? (Note & mark for repair)

1 ____________________ 3 ______________________ 5 ___________________

2 ____________________ 4 ______________________ 6 ___________________

Is the current in any service grounding connections excessive? Yes ______ No ______

Which wires? (Note & mark for repair)

Earth electrode _______________________ Water pipe ______________________

Building steel _____________________ Neutral to Ground Bond**** ____________

Is current in any feeder grounding conductor excessive? Yes ______ No ______

Which wire or breaker position? (Note & mark for repair)

1 ____________________ 3 ______________________ 5 ___________________

2 ____________________ 4 ______________________ 6 ___________________

Comments: ____

____

____

- * Check cause of voltage variation
- ** Check transformer grounding
- *** Check the water meter for bond and for bypass jumper
- **** Large amounts of current indicates either a wiring error or a parallel bond in the supply transformer

II Power Monitoring

If the data gathered during the physical inspection indicates that power monitoring is needed then the monitoring will be executed as follows:

1. Outside of the Facility

   - ❑ Look for construction, facility damage, power lines, the type of load, equipment being used around the exterior, etc.
   - ❑ Listen for arcing or other noises (possibly at the utility transformer).
   - ❑ Smell the air for anything out of the ordinary (burning, arcing).

2. Inside the Facility

- Look for construction, facility damage, the type of load equipment being used within the facility, etc.
- Listen for noises out of the ordinary.
- Smell the air for anything out of the ordinary (burning, arcing).

3. Check the Appropriate Panel Boards and Receptacles – BE SAFE

   - Look for physical damage, improper wiring, signs of wear, etc.
   - Listen for arcing or other noises.
   - Smell for burnt insulation or other odors.
   - Feel the panels and so forth for signs of overheating.
   - Measure the voltage and current in the conductors.

4. Decide on the Monitoring Location

   - At the malfunctioning equipment
   - At the power source – service entrance or transformer.
   - At the panel or corrective device output.

5. Decide on your Monitoring Plan

   - How long will you monitor (1 day, 1 week, 1 month, etc.)?
   - How often will you collect data from the monitor?
   - What are the appropriate thresholds?
   - Will you need to change thresholds of monitoring locations?

6. Set Up and Install Monitoring Equipment

   - Synchronize the unit(s) with the Customer's failure log clock.
   - Properly setup full configuration (use the same if using more than one unit).

7. Once you have Completed Your Monitoring Plan

   - Review the data you have collected.
   - Categorize the disturbances according to type, duration, magnitude, and whether it caused a failure or not.
   - Report on the data.

8. Help Decide the Corrective Action and Plan

   - Will rewiring be required?
   - Should a corrective device be added or removed?
   - Must the Customer move the failing device or source?
   - Doe the Customer want your involvement in the corrective action or is corrective action even required?

9. Monitor after the Corrective Action was Done

   - To verify the action taken was appropriate.
   - To see if there is more than one problem.
   - To finalize the monitoring process.

Important Notes - Keep These Points in Mind

- Most problems are simple and can be solved without sophisticated monitoring.
- What you are monitoring will always be affected by the monitoring equipment - therefore, minimize your impact. (Ground loops, etc.)
- A picture, literally, can be worth a thousand words.
- Verifying that an issue is not a problem is just as valid as showing it.
- A monitoring device is only as good as the experience and knowledge of the user.
- Problems usually exist like layers of an onion - peel away one layer and there may be another underneath.

- Be extra careful while in the customer's facility. Follow all of the customer's safety rules as well as all of Atlantic City Electric & Delmarva Power's safety rules. Some of these guidelines call for opening panels and switchgear, if you are not qualified , trained, or do not feel comfortable to do so, then do not perform the action. Ask the customer to do it if it is their equipment or request assistance from a qualified Atlantic City Electric & Delmarva Power employee. Your personal safety and the safety of those on site with you must always have the highest priority.

Interpretation of Monitoring Data: Some Rules of Thumb

In General,

- Impulses have a faster rise time the closer you are to the source.
- No “pure” load exists, rather it is some combination of those listed below.

Capacitive Components

- Disturbances generally occur near the peak of the sine wave, opposite in wave directions, as they take energy out.
- They typically have a “ringing” characteristic.
- Power supplies, single phase capacitive start motors and power factor correction capacitors switched on can cause these types of disturbances.
- An instantaneous upward or downward sustained voltage change can usually relate to capacitor switching.

Inductive Components

- Disturbances generally occur near the zero crossing of the sine wave as thy try to add energy back into the line.
- Typically, contact arcing is evident when disturbances occur.
- Motors being switched off can cause these types of disturbances.

Resistive Components

- Disturbances generally occur near the peak of the sine wave, opposite in wave direction, as they take energy out.
- Similar to capacitive disturbances, but they do not have a “ringing” characteristic (unless reactive components exist on the line also).
- Incandescent lights and heaters switched on can cause these types of disturbances.

Voltage Recorders

- An arcing voltage can create little bursts or voltage spikes as it arcs.
- A bad or defective neutral connection can cause the voltage recording to appear like a mirror image because of a neutral shift. One leg will go up and another will go down at the same time by the same amount. For example, on a nominal 120/240 volt, 3 wire service; you might find a voltage recording of 112/128/240 volts, which could be a bad neutral connection.
- A motor starting can produce a large voltage dip. The voltage dip or flicker may impact the one customer or many customers.
- A highly resistive connection can cause excessive voltage drop on that phase as well as heating up the connection.